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WIND PROBABILITIES AND TROPICAL CYCLONE READINESS CONDITIONS

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Wind probabilities are examined in relation to the establishment of tropical cyclone readiness conditions at Apra Harbor, Guam, and at Kadena AFB, Okinawa, Japan. By fitting a conceptual model to the data, decision zones are delineated for setting each condition. While these results apply strictly to the two stations alone, the concepts are general and can be made to apply to other bases and other problems.

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1. INTRODUCTION

One of the more serious decisions which routinely confronts the commander of a peacetime military base in the tropics is whether and when to order preventive measures as a tropical cyclone approaches. This is done by establishing one of a series of readiness conditions. In the case of typhoon force winds the conditions are defined as follow:

Condition IV	Typhoon force winds (winds in excess of 63 kt) are <u>possible</u> within 72 hours.
Condition III	Same as condition IV but within 48 hours.
Condition II	Typhoon force winds are <u>expected</u> within 24 hours.
Condition I	Typhoon force winds are <u>expected</u> in 12 hours.

The range of wind speeds for the conditions is variable but will usually be either: a) tropical storm force (34-63 kt); b) hurricane/typhoon force (over 63 kt); or c) over 50 kt.

With each condition there is a prescribed set of actions. These actions become progressively more intense and expensive as condition numbers approach I. For example, actions may range from requiring local commanders to review plans, procedures and bills (Condition IV) to a complete sortie of ships and aircraft capable of evading the disturbance area (Conditions II or I).

Under ideal circumstances conditions IV through I will be set at 72h, 48h, 24h and 12h before the onset of destructive winds. If conditions are set on schedule there will be 24, 24, 12 and 12 hours respectively within which to complete the required actions. Often actions carry over from one condition to another with the preparatory steps or phases occurring in earlier lower risk conditions. Completion

phases can then proceed rapidly when, and if, high risk (low numbered) conditions are actually established. This point is important because if early (high numbered) conditions are set late, there may not be sufficient time for orderly completion of subsequent evolutions. It is often necessary to either advance or retard setting a condition to allow sufficient daylight to complete required tasks. While conditions III and IV will ideally contain 12 hours of daylight, parts of conditions I and II will probably be executed in darkness. Where military families and civil service employees are a consideration, one must not only plan ahead for darkness, but also for weekends and holidays, since it then becomes difficult to communicate with personnel. Commanders are also concerned that premature or unnecessary conditions waste industrial productivity (i.e., at repair facilities) and increase overtime wages; particularly during nights, holidays and weekends.

When a tropical cyclone moves consistently toward a station, setting conditions becomes a matter of timing; balancing between accepting a minimum risk of being underprepared while seeking to avoid unnecesary waste of resources in over preparation.

The event usually will not evolve in an orderly, consistent fashion. It is more apt to occur in one, or a combination of the three following scenarios:

a) The storm will be forecast to miss, will behave and do just that. In this case the problem is to avoid wasting resources by being over cautious.

b) The storm will be forecast to hit but will instead miss. Again, the problem is to avoid wasting resources, but caution is more clearly warranted.

c) The storm will be forecast to miss but will at some point turn and strike. This is, of course, the toughest problem. The prudent decision maker will be skeptical of the forecast (as he should in scenario (a) also) and he will position himself so that he can act rapidly. This may include setting high numbered conditions (prematurely) which increase preparedness, or it may include the setting of some modified condition.

2. *PROBLEM*

The problem, in readiness condition related decisions, is to find the proper tradeoff between risk taking (undercaution) and overcaution. A cost is associated with each of these. When one is undercautious he risks unnecessary or avoidable losses. The overcautious commander expends resources unnecessarily. There is a rule from economic theory which uses the ratio of <u>cost of actions</u> to <u>avoidable losses</u> or cost benefit ratio (CBR) as an index to acceptable risk. In the long term, costs are minimized if actions are taken only when the probability of the event is greater than the cost benefit ratio.

Immediately there are three problems associated with this relationship. The first is that it is difficult to estimate the costs related to setting conditions. The second and more severe problem is that of estimating avoidable losses. The third problem relates to estimating probabilities. Only in the latter has some realistic progress been made.

Beginning in 1979, "tropical cyclone wind probabilities" (WINDP) have been available: first for northwest Pacific typhoons, then for Atlantic hurricanes, northeast Pacific hurricanes and recently for the cyclones of the north Indian Ocean. In their present form, these provide the probabilities that 30 or 50 kt winds will occur at a point (military base or other point of strategic importance) within a period of time, or precisely at a particular time. The former are integrated over the time period and are relevant for this study. The latter are referred to as instantaneous and apply best for moving targets (ships and airplanes).

The concept of using the wind probabilities to aid commanders in setting conditions has been hampered because cost benefit ratios have not been determined and further the prospects of such determination are not bright.

Appendix A presents a brief case study of Atlantic hurricane David approaching and striking Dominica in the Lesser Antilles. That study suggests the utility of wind probabilities as a guage to the threat posed by an approaching hurricane or typhoon. Wind probabilities compared to usual measures of threat present a picture of steady consistent information compared with the wavering, on-again, off-again behavior of more traditional indices of threat.

The purpose of this study is to examine the wind probabilities as they relate to the establishment of actual conditions. The methodology used was to identify upper and lower bounds on wind probabilities associated with the

setting of each condition; analyze the results and present them in a nomograph as an aid to the decision-maker.

3. APPROACH

The data consisted of 26 situations (from 1977 through 1981) in which tropical cyclones threatened either Apra Harbor, Guam or Kadena AB, Okinawa, Japan. Joint Typhoon Warning Center, Guam (JTWC) forecasts were obtained for the period of the threat and wind probabilities were computed from these warnings just as they are operationally. Records of tropical cyclone conditions in effect were obtained from the Naval Oceanography Command Center on Guam and from the 30th Weather Squadron on Okinawa.

After wind probabilities were computed, those which corresponded to the times when readiness conditions were set were identified. The wind probabilities, based on routine operational forecasts issued at six hourly intervals, were treated as though they were the only information available for the six hour period beginning one hour prior to their issue (this allows for preliminary release of critical information). It should be noted that during most of this time, wind probabilities were not operationally available; hence we are trying to relate the perceived threat to wind probabilities regardless of the basis for that perception.

A commander's perception as to when to change or set a condition could be based upon many variables other than wind speed. However, by examining many cases an average "decision zone" (related to wind) for each condition change can be determined. The lower limit of the 'zone'would delineate the

upper limit for <u>not setting</u> the condition. The upper limit for the 'zone' would delineate the lower limit for <u>setting</u> the next condition. Between these two limits lies a grey area called the decision zone in which the condition may or may not be set depending upon other impinging factors.

In looking for threshold values which commanders might be using as guidance on when to set or establish conditions, it was assumed that not setting conditions would indicate perceived threats below those thresholds. The time of the maximum wind probability (highest expected threat of below threshold threats) was then considered to have been the time of "not-setting" that condition. This applies when a condition is in effect and the next level threat condition is being considered. If a lower numbered condition (higher threat) was set directly without going through the next higher numbered condition, the time of "not-setting" the higher condition was deemed to have been 12 and 24 hours earlier for conditions II and III, respectively. The bulk of this report presents an analysis of wind probabilities which were recorded at these "set" and "not set" times.

4. DISCUSSION

One problem at issue here is that conditions were not uniformly defined nor applied over the period of the study. In general there was a threatening wind level and a time within which the threat applied.

The times remained constant as within 12, 24 and 48 hours for conditions I, II and III. Condition IV, 72 hours is generally a seasonal condition and although it was

actively set/relaxed at Kadena for a part of the study period, is not considered here.

The theatening wind speed at Kadena was uniformly 50 kts. In contrast, at Apra there was the possibility of setting a tropical depression, tropical storm or typhoon condition prior to 1980 with each implying its own range of threatening winds. However, beginning with 1980 a system of tropical cyclone conditions was implemented in which the threatening wind was always specified. To some extent these differences are isolated by stratifying the data.

The information recorded was the STRIKP*, 30 kt ar 50 kt WINDP integrated** over the lead time associated .n the condition. Also recorded was the 72 hour (or last 'e-cast) 30 kt and 50 kt time integrated WINDPs. The loc me and the day of the week were also determined for each situation since these are known to be factors in the effectiveness and cost of setting conditions. Table 1 lists the information recorded for each situation and also contains a statistical data summary for the probabilities in the situations where conditions were set.

---

*STRIKP is strike probability, the probability that the cyclone will pass thorugh a small area surrounding the station.

**The term integrated refers to the total probability of the event (winds of at least 30 or 50 kt) occurring at a point within an interval of time as opposed to a particular time. A 72 hour time integrated probability provides the likelihood that the event will occur at least once during the 72 hour period.

CONDITION I (12 HR)

YEAR	NAME	STA	LST MODAHR	DOW	G B	STK	W50	W30	W50M	W30M
1977	VERA	K	072915	SAT	B	(35)	(33)	(76)	(33)	(76)
	BABE	K	090923	FRI	B	49	63	82	63	82
	KIM	A	110811	WED	G	51	38	73	41	73
	MARY	A	122918	MON	G	36	13	55	24	57
1978	VIRGINIA	A	072410	MON	G	(00)	(00)	(07)	(10)	(22)
	CARMEN	K	081502	TUE	B	53	49	75	49	75
	FAYE	A	082810	MON	G	(55)	(18)	(50)	(19)	(50)
	ORA	K	101320	FRI	B	00	03	52	23	56
	RITA	A	102315	MON	G	37	55	67	55	57
1979	ALICE	A	010919	TUE	B	32	49	83	50	83
	IRVING	K	081417	TUE	G	04	29	85	31	85
	JUDY	K	082115	TUE	G	17	45	82	56	86
	OWEN	K	092622	TUE	B	13	39	81	44	81
	TIP	A	100912	TUE	G	45	25	65	29	65
	TIP	K	101721	WED	B	13	48	95	58	95
	ABBY	A	120816	SAT	B	(31)	(06)	(49)	(09)	(49)
1980	ELLEN	A	051604	FRI	G	(03)	(27)	(65)	(33)	(67)
	NORRIS	K	082709	WED	G	(01)	(04)	(53)	(14)	(53)
	ORCHID	A	091015	WED	G	00	18	80	18	80
	WYNNE	A	100615	MON	G	(59)	(37)	(63)	(37)	(63)
	BETTY	A	103107	FRI	G	87	73	86	73	87
	DINAH	A	112216	SAT	B	(04)	(14)	(70)	(20)	(76)
1981	GERALD	A	041920	SUN	B	00	00	17	00	18
	HOLLY	A	050313	SUN	B	(00)	(00)	(01)	(17)	(31)
	IRMA	A	112004	FRI	G	(69)	(45)	(67)	(45)	(67)
	JEFF	A	112322	MON	B	67	17	51	19	52
				MIN		00	00	17	00	18
				MEAN		32	35	70	40	71
				MAX		87	73	95	73	95
				STDEV		28	23	26	22	26
				SET CASES				16		

CONDITION II (24 HR)

YEAR	NAME	LST MODAHR	DOW	G B	STK	W50	W30	W50M	W30M
1977	VERA	072915	SAT	B	(36)	(33)	(76)	(33)	(76)
	BABE	090902	FRI	B	31	52	84	52	84
	KIM	110808	WED	G	25	19	47	22	47
	MARY	122806	SUN	B	(09)	(02)	(23)	(14)	(30)
1978	VIRGINIA	072410	MON	G	(00)	(00)	(07)	(10)	(22)
	CARMEN	081421	MON	B	64	59	88	59	88
	FAYE	082810	MON	G	(55)	(18)	(50)	(19)	(50)
	ORA	101215	THU	G	00	00	07	00	07
	RITA	102306	MON	G	19	39	69	43	70
1979	ALICE	010820	MON	B	07	23	68	38	72
	IRVING	081322	MON	B	21	26	63	28	63
	JUDY	081922	SUN	B	00	02	39	23	48
	OWEN	092515	MON	G	14	21	66	28	66
	TIP	100908	TUE	G	26	23	55	26	55
	TIP	101715	WED	G	38	55	91	55	91
	ABBY	120804	SAT	B	(18)	(12)	(39)	(17)	(40)
1980	ELLEN	051604	FRI	G	(12)	(33)	(67)	(33)	(67)
	NORRIS	082703	WED	G	(05)	(11)	(53)	(14)	(53)
	ORCHID	091007	WED	G	15	28	72	28	72
	WYNNE	100616	MON	G	59	37	63	37	63
	BETTY	103016	THU	G	53	49	81	50	81
	DINAH	112219	SAT	B	06	20	76	20	76
1981	GERALD	041906	SUN	B	03	05	44	06	44
	HOLLY	050313	SUN	B	(01)	(01)	(14)	(17)	(31)
	IRMA	111915	THU	G	40	21	53	25	53
	JEFF	112314	MON	G	26	17	44	23	44
			MIN		00	00	07	00	07
			MEAN		25	27	62	31	62
			MAX		64	59	91	59	91
			STDEV		21	19	25	18	25
			SET CASES				18		

CONDITION III (48 HR)

YEAR	NAME	LST MODAHR	DOW	G B	STK	W50	W30	W50M	W30M
1977	VERA	072900	FRI	G	31	20	54	21	54
	BABE	090802	THU	G	(09)	(18)	(49)	(19)	(49)
	KIM	110709	TUE	G	16	18	38	20	38
	MARY	122706	SAT	B	(01)	(01)	(14)	(11)	(24)
1978	VIRGINIA	072319	SUN	B	03	04	15	07	18
	CARMEN	081415	MON	G	42	41	70	42	70
	FAYE	082712	SUN	B	(55)	(19)	(50)	(19)	(50)
	ORA	101109	WED	G	10	10	25	12	27
	RITA	102114	SAT	B	11	21	50	24	50
1979	ALICE	010809	MON	G	17	28	61	29	61
	IRVING	081319	MON	B	27	30	71	31	71
	JUDY	081918	SUN	B	06	14	38	20	39
	OWEN	092506	MON	G	15	20	42	21	42
	TIP	100820	MON	G	18	21	43	22	43
	TIP	101616	TUE	G	18	30	75	31	75
	ABBY	120512	WED	G	12	18	48	22	48
1980	ELLEN	051516	THU	G	17	24	69	24	69
	NORRIS	082702	WED	G	06	10	52	11	52
	ORCHID	091003	WED	G	16	29	72	29	72
	WYNNE	100603	MON	G	34	17	47	19	48
	BETTY	103008	THU	G	20	23	48	24	48
	DINAH	112200	SAT	B	16	15	31	15	31
1981	GERALD	041616	THU	G	12	19	40	20	40
	HOLLY	050208	SAT	B	12	15	34	19	35
	IRMA	111912	THU	G	25	20	40	21	40
	JEFF	112311	MON	G	27	21	44	23	44
			MIN		01	04	15	07	18
			MEAN		16	19	47	20	07
			MAX		34	30	75	31	75
			STDEV		10	08	18	08	19
			SET CASES				23		

Table 1. Tabulation of data recorded about each situation. STA is station A = Apra Harbor, Guam and K = Kadena AB, Okinawa. MODAHR is the local date time (nearest hour), DOW is day of the week. G/B represents good or bad (convenient or inconvenient) time. STK, W50, W30 W50M and W30M are the time integrated strike, 50 and 30 kt wind probabilities for lead time (12, 24 or 48 hours) and the maximum 50 and 30 kt wind probabilities (usually 72 hours). Numbers in parentheses indicate values when conditions were not set but considered. Summary statistical data involves only cases where conditions were set.

By inspection, the WINDP's relate to the actual threat much better than the associated STRIKP's. However, the STRIKP'S used in conjunction with the WINDP's permit a subjective partitioning of the source of the forecast uncertainty. Except for an occasional reference in that connection, the STRIKP's were not analyzed.

Maximum WINDP values were compared to WINDP values for the time associated with the various conditions. The maximum value will always be the time integrated value over the longest forecast period, usually 72 hours. The time integration process causes the integated sum to change very little after the forecast closest point of approach to the location in question. It follows that the time integrated WINDP of greatest interest is little different from the maximum value.

Table 2 compares the lead time forecasts of 30 and 50 kt WINDP values to the corresponding 72 hour (or maximum) WINDP forecasts when conditions were set.

		W50		W50M		W30		W30M	
COND	TIME	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
I	12h	35.3	23.1	39.6	22.3	70.5	26.4	71.4	26.4
II	24h	27.4	19.2	31.4	18.3	61.5	25.2	62.4	25.0
III	48h	18.4	7.8	20.1	7.8	46.8	18.1	47.1	17.7

Table 2. Comparison of means ($\overline{X}$) and standard deviations (S) of W50 and W30 versus W50M and W30M at the time each of three conditions were set. Time refers to condition lead time. W30M and W50M are maximum time integrated wind probabilities.

Differences between means were small, ranging up to 4%. In individual cases they were considerably larger, but the large differences were attributed to cases where the conditions were set too early. (See Table 1. For Judy, both conditions II and III were set early relative to condition I.)

The implication is that it is only necessary to examine W50M and W30M for guidance. Little is gained by examining the entire set of time integrated probabilities. The other values are still useful, however, because they show the time evolution of the threat. For the remaining comparisons, only the maximum time integated WINDP's, W50M and W30M, will be considered.

The next comparison presented in Table 3 is for the setting of conditions at Kadena vs Apra. Table 3 compares average values of the W50M, W30M pairs for Apra to those of Kadena and those of the entire sample. Separate comparisons are given for conditions I, II and III for "set" and "not set" cases.

		APRA		KADENA		BOTH	
		W50M	W30M	W50M	W30M	W50M	W30M
COND I	SET	35.4	62.8	42.8	80.0	39.6	71.4
	NOTSET	23.8	53.1	23.5	64.5	23.7	55.4
COND II	SET	28.8	60.5	34.1	64.9	31.2	62.4
	NOTSET	18.3	40.0	23.5	64.5	19.6	46.1
COND III	SET	20.6	43.8	24.1	55.8	22.0	48.5
	NOTSET	15.0	37.0	18.0	49.0	16.0	41.0

Table 3. Comparison of average values of W50M and W30M for Apra, Kadena and both, for three readiness conditions either being "set" or "notset".

It is interesting to note that consistently, the decisions at Kadena are made at higher threat levels. This is the opposite of what was expected since most Navy conditions were for 64 kt+ (typhoons) and at least tropical storm strength (34-63 kt) whereas the Air Force always set conditions for 50 kt winds. We therefore would expect the Navy conditions to be set less frequently or at higher probability levels. Table 3 suggests a higher cost benefit ratio at Kadena. That is, either the cost of preparation is higher or the value of avoidable losses is lower or both.

The not setting of conditions suggests a risk level which was deemed acceptable by the decision maker at the time. Thus we can infer that an average threshold exists somewhere in the grey area between the average values for the "set" and the "not-set" cases. This provides a range which permits the flexibility required to accommodate advancing the setting of a condition to catch daylight or non weekend hours or slowing the setting of a condition to await regular work hours. It also maximizes the use of available time while holding the payment of overtime to a minimum.

The last comparison, presented in Table 4 looks at this concept of poor times to set conditions versus good times. Poor times are defined here as Saturday, Sunday (or holidays) and, for conditions II and I, also include the hours from 1600 to 0400L.

		POOR W50M	POOR W30M	GOOD W50M	GOOD W30M
COND I	SET	38.3	67.8	41.0	75.0
	NOTSET	19.8	58.0	26.3	53.7
COND II	SET	32.3	67.9	30.5	59.0
	NOTSET	20.3	44.3	19.0	48.0
COND III	SET	19.3	40.7	22.9	51.2
	NOTSET	16.0	41.0	DID NOT OCCUR	

Table 4

Comparison of average values of W50M, W30M for "set" and "notset" cases under poor and good timing situations, for each of the 3 readiness conditions.

Rational behavior suggests that the acceptable threat level be higher during poor times if the cost of action is higher (i.e., as it appears to be considering overtime and personal inconvenience, etc.). In 6 of the 10 possible comparisons of corresponding values under good or poor conditions in Table 3, the "poor" time average values for setting conditions were smaller than the corresponding "good" values. Some irrational behavior (panic?) or other considerations must therefore come into play here.

5. A MODEL

An acceptable risk model (CHARM©, SAI 1982) aimed primarily at civil populations, relates wind probabilities to readiness conditions comparable to those of the Defense Department. The assumptions that form the basis of CHARM are as follows:

1) That a composite cost benefit ratio (ratio of the cost of setting condition to avoidable losses if condition is not set and damaging winds occur) can be estimated.

2) That there is a defined period of time required to complete the action before the onset of some disruptive wind level.

3) That should the action be interrupted, action would have been taken in proportion to the amount of time available to that required. A similar proportion of the cost is assumed to have been incurred and avoidable loss proportional to the unfinished action would be sustained should the damaging winds occur.

As indicated earlier economic theory suggests one should prepare (set the condition) when the probability of the occurence of the damaging condition (P_d) is at least as great as the cost benefit ratio (CBR).

Symbolically this is expressed: Act only if $P_d > CBR$. The CHARM model equation has the form: Act only if $P_d > CBR \times f(P_1,h)$ where $f(P_1,h)$ is a function of the probability of disruptive winds (P_1) and required lead time (h) before destructive winds.

This relationship is shown graphically in figure 1 for arbitrary cost benefit ratios. The decision whether to set a condition or not is made on the probability of the destructive wind P_d. On the other hand, the timing is controlled largely by the probability of the disruptive wind P_1.

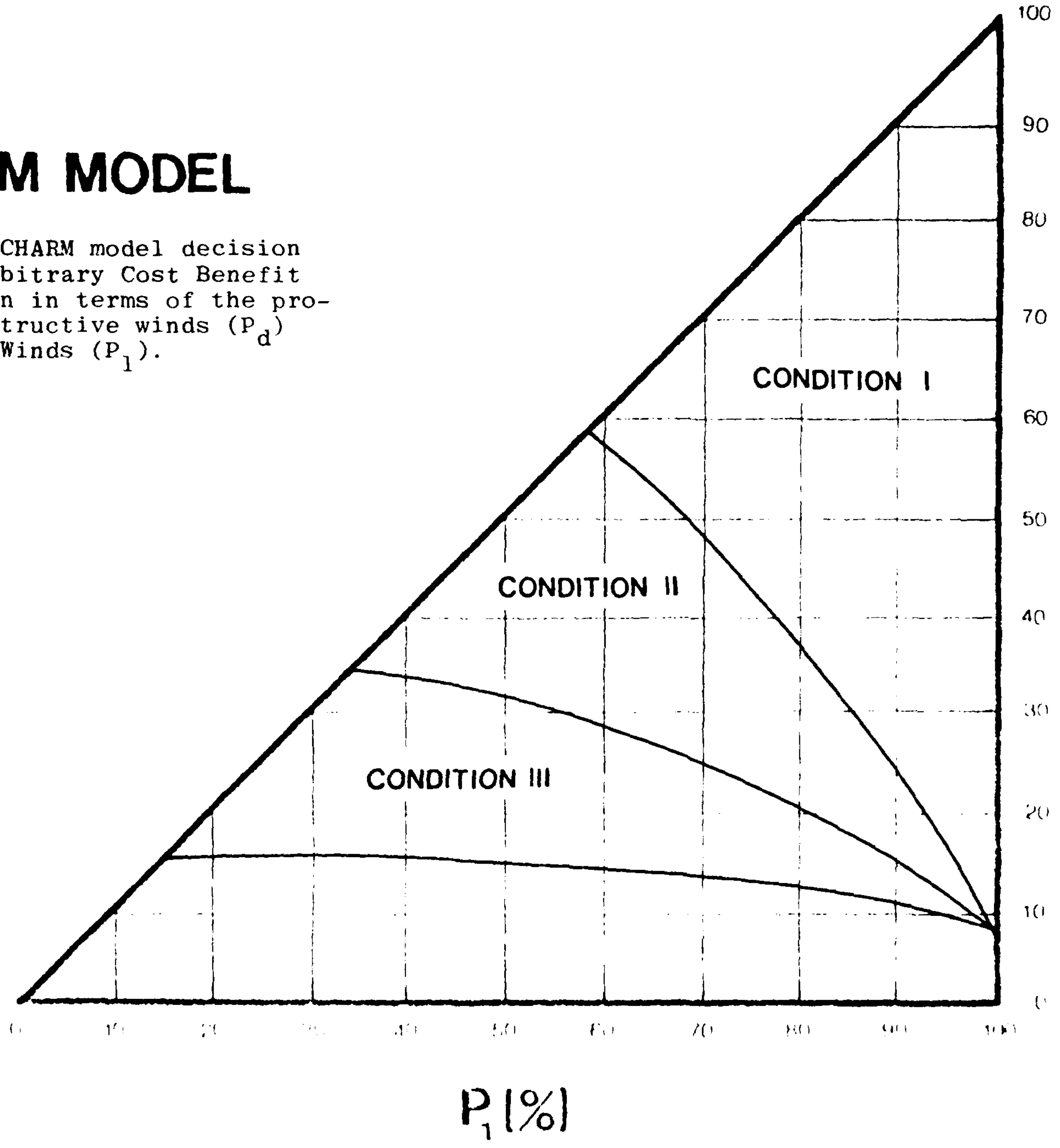
Fitting the CHARM model to the data of Table 2 implies the following brackets on CBR at Apra and Kadena.

	APRA	KADENA
COND I	.536<CBR<.313	.980<CBR<.367
COND II	.389<CBR<.206	.489<CBR<.335
COND III	.221<CBR<.158	.273<CBR<.197

We can reduce the limits somewhat by noting that the cost benefit ratio of a lower numbered condition must be greater than that of a higher numbered condition (otherwise we set the lower numbered condition earlier and more often). For example CBR for condition I at Apra is greater than .313 and the CBR for condition II is less than .389. It is reasonable to adopt a compromise boundary there. An average is a compromise which violates neither inequality. Taking averages when appropriate, the resulting CBR ranges are:

CHARM MODEL

Figure 1. The CHARM model decision criteria for arbitrary Cost Benefit Ratios are shown in terms of the probability of destructive winds (P_d) and Disruptive Winds (P_1).



	APRA	KADENA
COND I	.536<CBR<.351	.980<CBR<.428
COND II	.351<CBR<.214	.428<CBR<.335
COND III	.214<CBR<.158	.273<CBR<.197

Figures 2, 3 and 4 are nomographs for Apra depicting setting of conditions based on an approach comparable to the one set of figure 1. Figure 2 corresponds to the average W50M and W30M when condition III was not set or was set. Figures 3 and 4 correspond to the average W50M and W30M values associated with setting or not setting conditions II and I. All depict the grey area wherein the condition may or may not be set.

Figures 5, 6 and 7 are similar nomographs for Kadena.

6. CONCLUSIONS AND RECOMMENDATIONS

If the CHARM assumptions are reasonable for Apra or Kadena, then the nomographs given as figures 2 through 7 represent reasonable limits on the threshold values for setting conditions. The intent here is that average "not-set" values represent a lower limit on the reasonableness of conditions. Setting conditions on probabilities below these limits is likely to prove overcautious. On the other hand, it is suggested that conditions should be set by the time the "set" average is reached. Setting conditions on probabilities above these limits is likely to be considered imprudent over the long run.

To the extent that other stations are similar in preparation costs vs potential loss to Apra or Kadena, and to the extent the CHARM assumptions hold, these thresholds could apply there also. It is <u>not</u> reasonable to expect that a cost benefit analysis could refine the estimates for these two

stations appreciably, but such a study may be the only realistic way to estimate threshold values for other stations and other problems where records will not support the type analysis conducted here.

Some adjustment could be made to the nomographs to reflect unusual conditions. For example, expensive material may be exposed during a construction project or during a deployment for an operation, thus the potential for avoidable damage may be high. Similarly, around midday, it may be preferable to set a condition early to gain some daylight. Either of these situations has the effect of reducing the action threshold probability. (Thus a small probability may exceed the threshold).

On the other side, when favorable circumstances make conditions less necessary, (e.g., unusual absence of aircraft, or ships under repair), the value of the condition is somewhat less and its relative cost to set (CBR) is greater. Then action threshold probabilities are higher.

Instead of changing the nomographs, we can create the same effect by adding (or subtracting) a small amount to (from) the probabilities to subjectively allow for unusual circumstances. Since this is likely to be confusing the following simple rule is offered:

> For unusual arguments favoring the immediate setting of a condition, add up to 10% to the W30M. For unusual arguments against the condition subtract up to 10% from W30M. After these adjustments, then enter the nomograph. Note that the modified W30M must still be constrained to the 0-100% range. A change to W30M has the effect of speeding up or slowing the timing of the condition and has a smaller effect than

W50M. Adjusting by even 10% would be reasonable for distinctly unusual conditions. It is <u>not</u> reasonable to add or subtract more than one 10% increment to account for multiple arguments although cancellation of any adjustment by offsetting arguments is appropriate.

For commanders and advisors who choose to use the nomographs of figures 2 through 7, it is recommended that you begin tentatively. If your point receives frequent threats (like Guam or Okinawa) use the nomograph after the fact for the first few trials to get the feel for how well it works.

For the vast majority of users, you may only get to use it once. To simulate "practice", it is suggested you practice on other stations as they are threatened. As a hurry up crash course, you might try using the information in Table 1 along with the annual typhoon reports to recreate the situations at Guam or Kadena.

APRA CONDITION III CASES

Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition	-10% ←•→ +10%	Unusual Factors Suggest Setting Condition

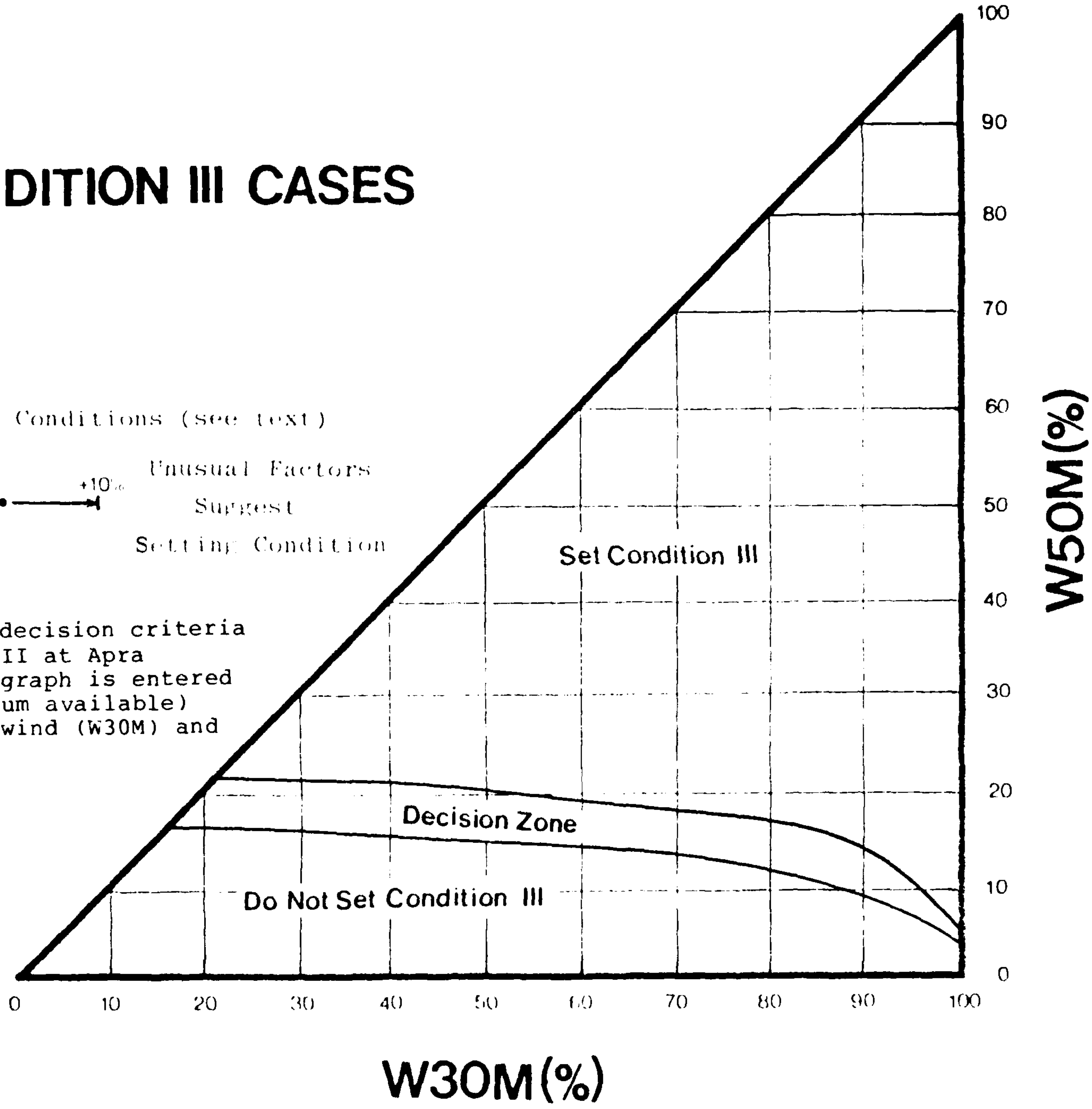


Figure 2. Depicts the decision criteria for setting Condition III at Apra Harbor, Guam. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

APRA CONDITION II CASES

Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition	-10% ——•—— +10%	Unusual Factors Suggest Setting Condition

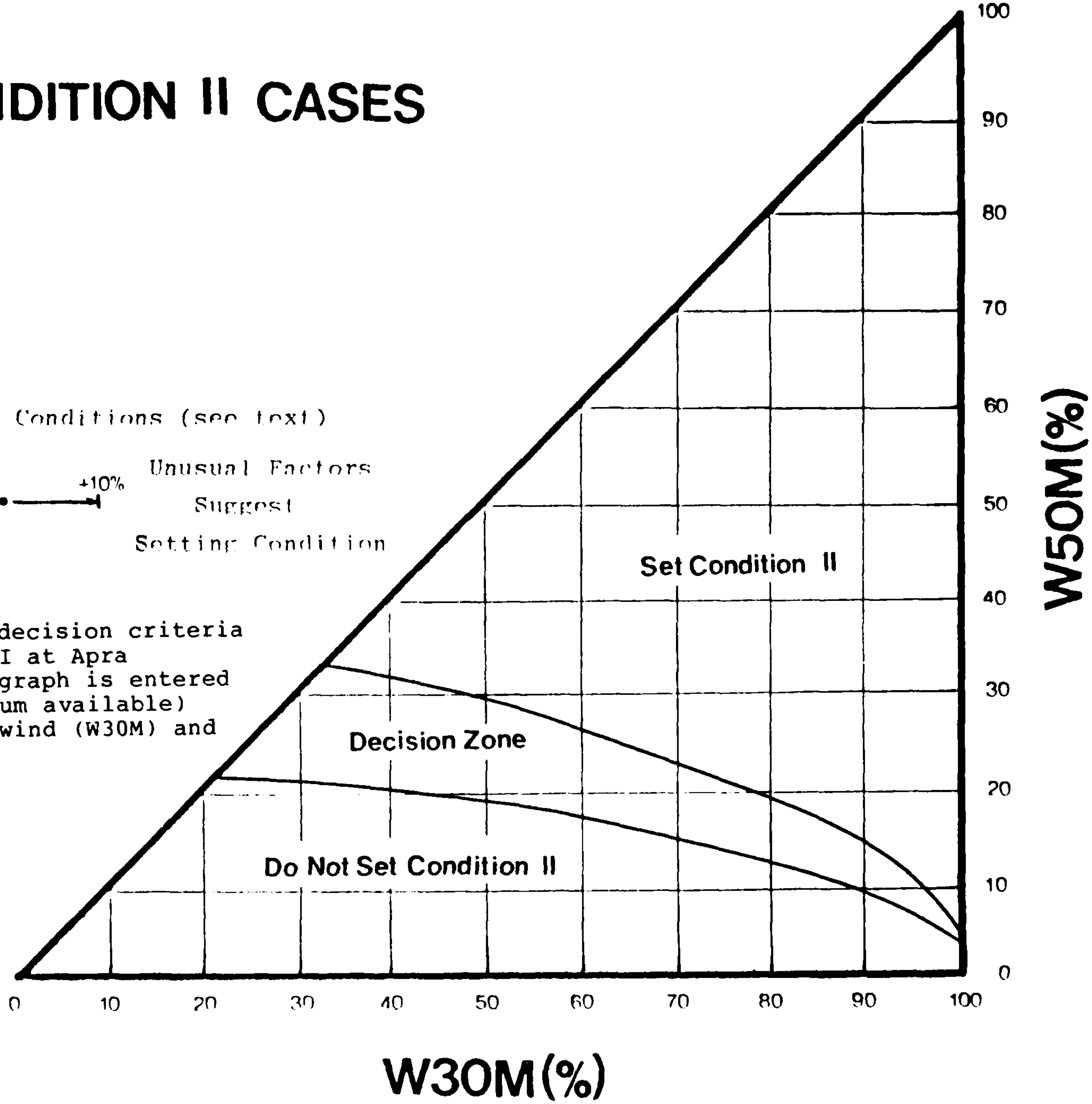


Figure 3. Depicts the decision criteria for setting Condition II at Apra Harbor, Guam. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

APRA CONDITION I CASES

Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition	-10% ←•→ +10%	Unusual Factors Suggest Setting Condition

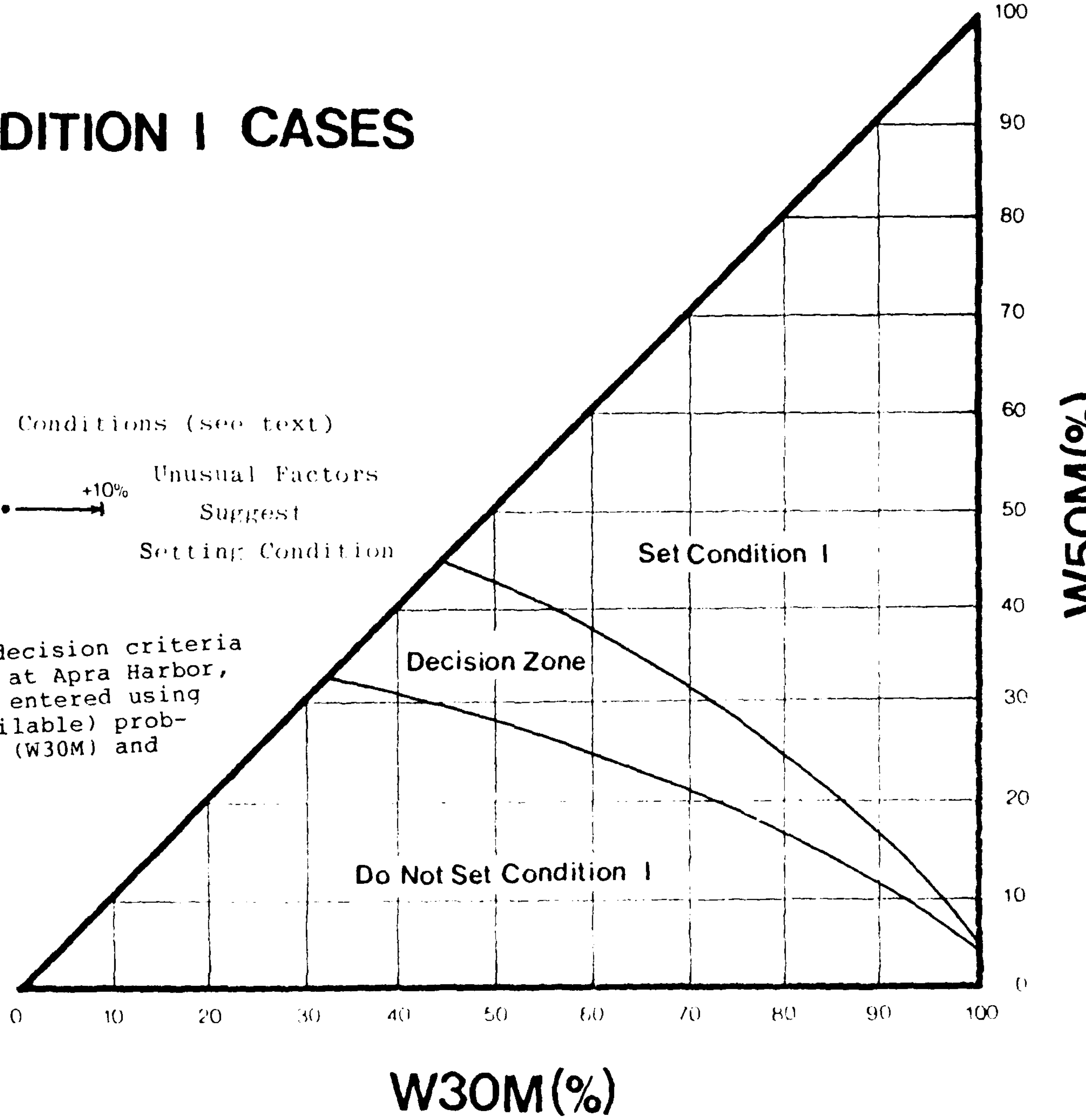


Figure 4. Depicts the decision criteria for setting Condition I at Apra Harbor, Guam. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

KADENA CONDITION III CASES

Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition	-10% ← • → +10%	Unusual Factors Suggest Setting Condition

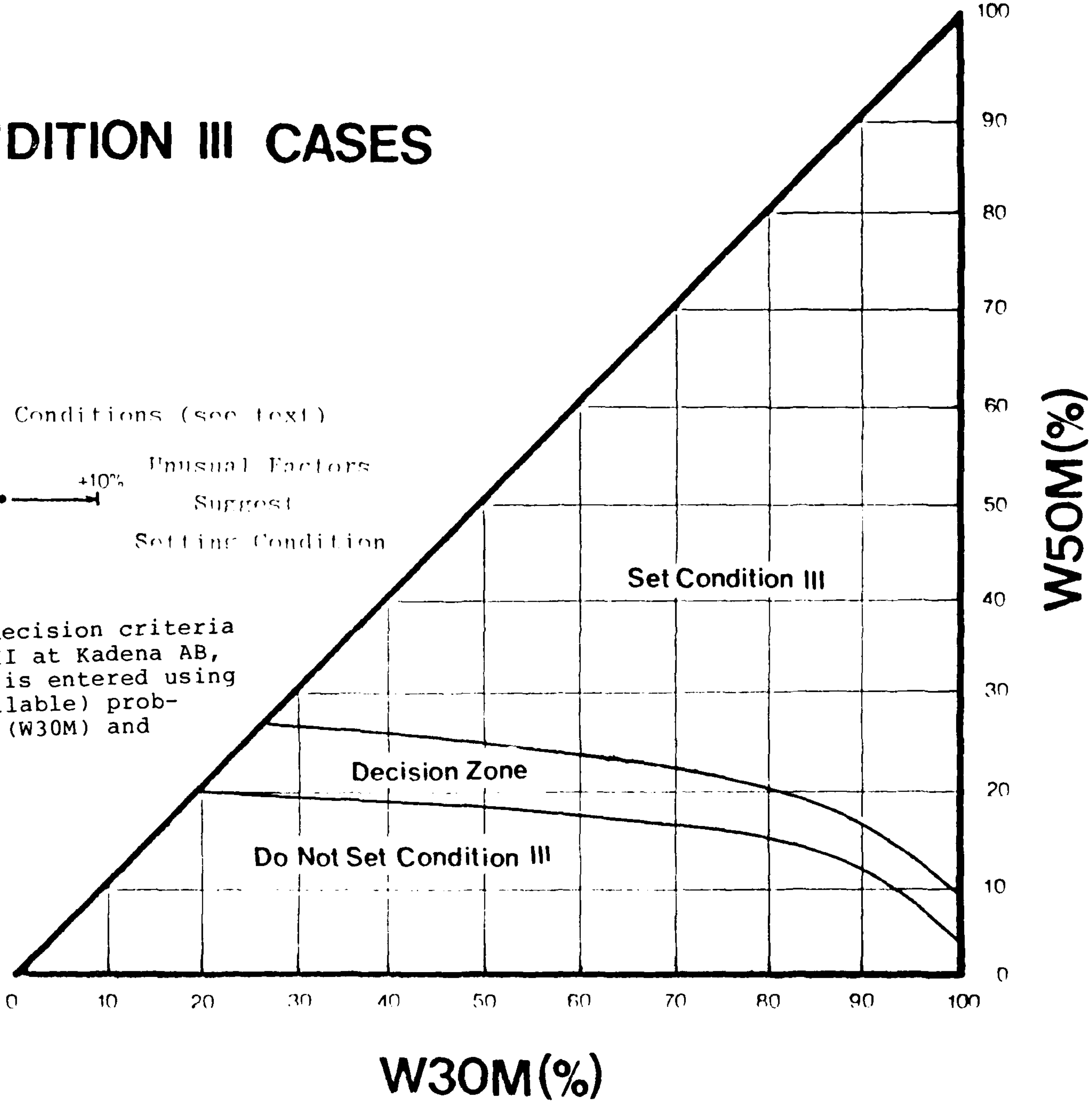


Figure 5. Depicts the decision criteria for setting Condition III at Kadena AB, Okinawa. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

KADENA CONDITION II CASES

Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition	-10% ←—•—→ +10%	Unusual Factors Suggest Setting Condition

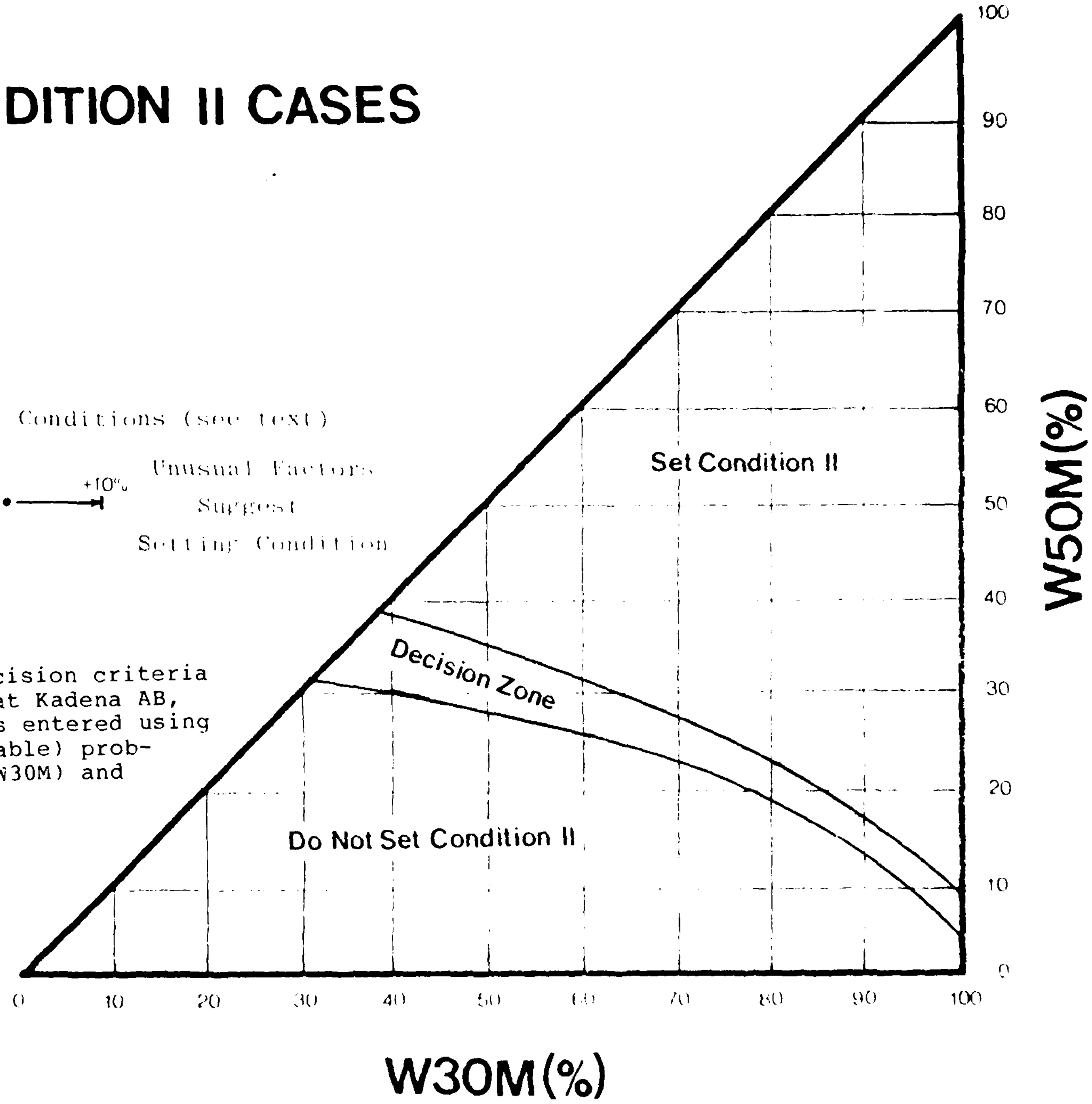
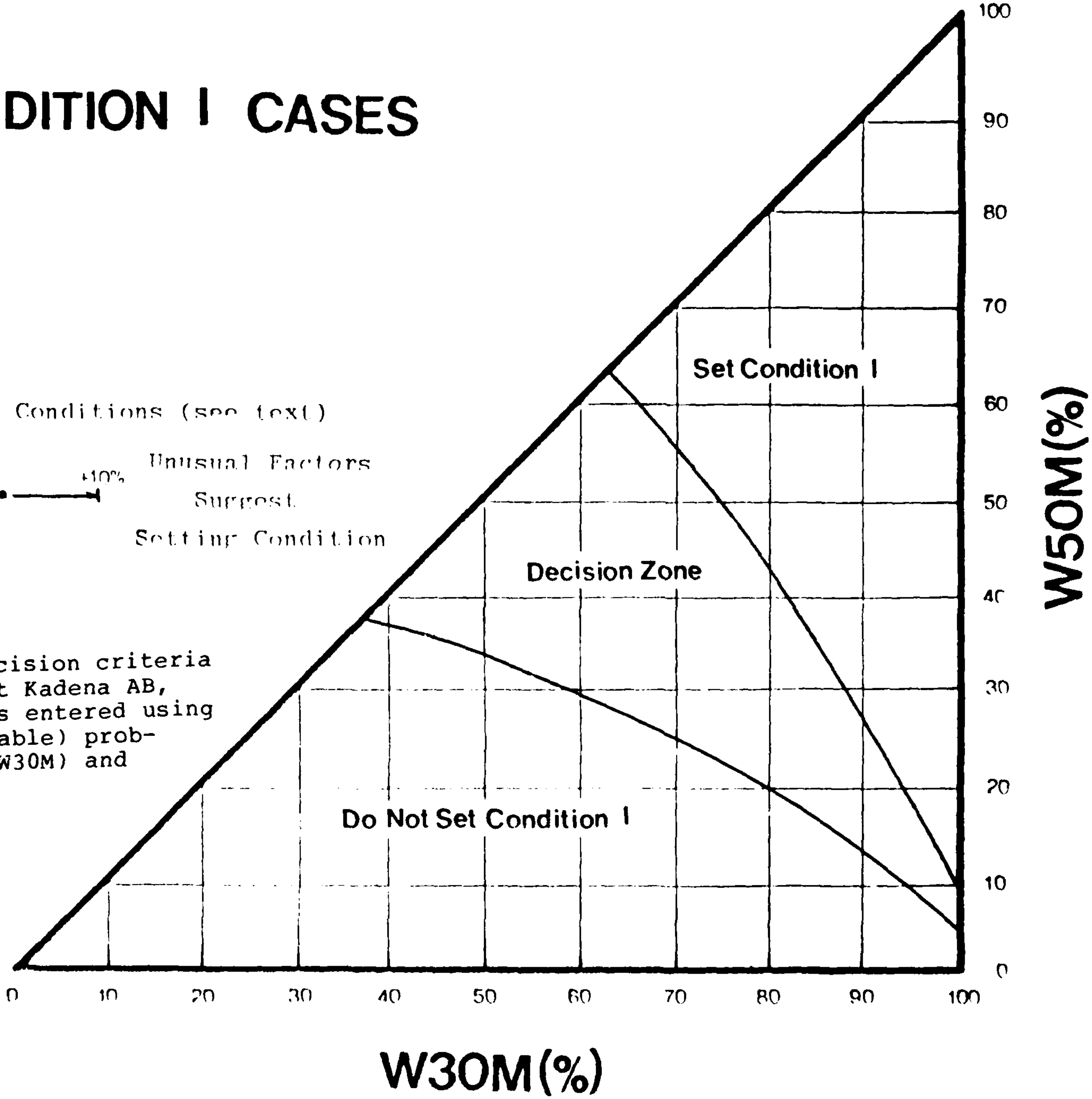


Figure 6. Depicts the decision criteria for setting Condition II at Kadena AB, Okinawa. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

KADENA CONDITION I CASES



Adjustments for Unusual Conditions (see text)

Unusual Factors Suggest Not Setting Condition -10% ——•—— +10% Unusual Factors Suggest Setting Condition

Figure 7. Depicts the decision criteria for setting Condition I at Kadena AB, Okinawa. The Nomograph is entered using 72 hour (or maximum available) probabilities of 30 kt wind (W30M) and 50 kt wind (W50M).

Appendix A

Case Study: Hurricane David and Dominica

On 29 August 1979, Atlantic Hurricane David struck the island of Dominica with 120-130 kt winds killing 56 people (of 80,000), causing major crop damage and leaving fully 75% of the population homeless. Despite the apparent steady approach over the preceeding three or four days, the island and the capitol city of Rosseau were caught by surprise. The purpose of this case study is to look at the forecasts to determine why the message of increasing threat was not communicated to the authorities at Rosseau, and to look at an alternative method to evaluate an approaching hurricane.

To summarize what happened prior to looking at why it happened, an examination of the known information available to Rosseau may be helpful. Basically the information source for David forecasts was the local Antilles commercial radio. Presumably they were receiving and passing along public advisories from the U.S. National Hurricane Center (NHC) in Miami. David had been mentioned locally since the 25th or 26th and had been considered a developing threat to the island group in general.

Based on a narrative by an eyewitness in Dominica, the following summarizes the Radio Antilles broadcasts:

(1) The first broadcast to pose an actual threat for Dominica was midday on the 28th of August - <u>24</u> hours prior to the actual hurricane strike.

(2) At 10 PM (28 Aug) it was known that the storm would miss Barbados and was threatening Martinique and St. Lucia. (Thus the storm had turned north-northwest and was a definite threat to Dominica by extension of the possible route.) Storm warning was in effect for Dominica.

(3) The early report at 6 AM on the 29th correctly reported that David would pass over Dominica. Confusion later ensued when Radio Antilles reported that the hurricane posed no threat to Martinique or St. Lucia and gave no report for Dominica. This left Dominicans to draw their own conclusion.

(4) Local communications on Dominica broke down sometime during the evening of the 28th further confusing events.

Since the Dominicans used Radio Antilles for their warnings it is assumed that this was the best information available to them.

Other Information:

Not generally available to the Dominicans were NHC point forecasts which are issued to U.S. military interests at 6 hour intervals. These forecast the track and winds out to 72 hours and appear to be consistent with the Radio Antilles reports suggesting both had the same root source (NHC).

Figure A-1 shows the track followed by David to Rosseau and beyond. Figures A-2 and A-3 depict the NHC military forecasts over the 72 hours preceeding arrival at Rosseau. Each forecast is labelled with a Date/Time, the actual and forecast lead time before the closest point of approach, a forecast passing distance at the closest point of approach and maximum winds forecast for Rosseau.

An examination of figure A-2 reveals that except for some timing problems the first four forecasts are almost perfect. However at 48 hours lead time a rather minor shift southward of the mid section of the forecast track suggests a greatly reduced threat to Rosseau as shown on the bottom of

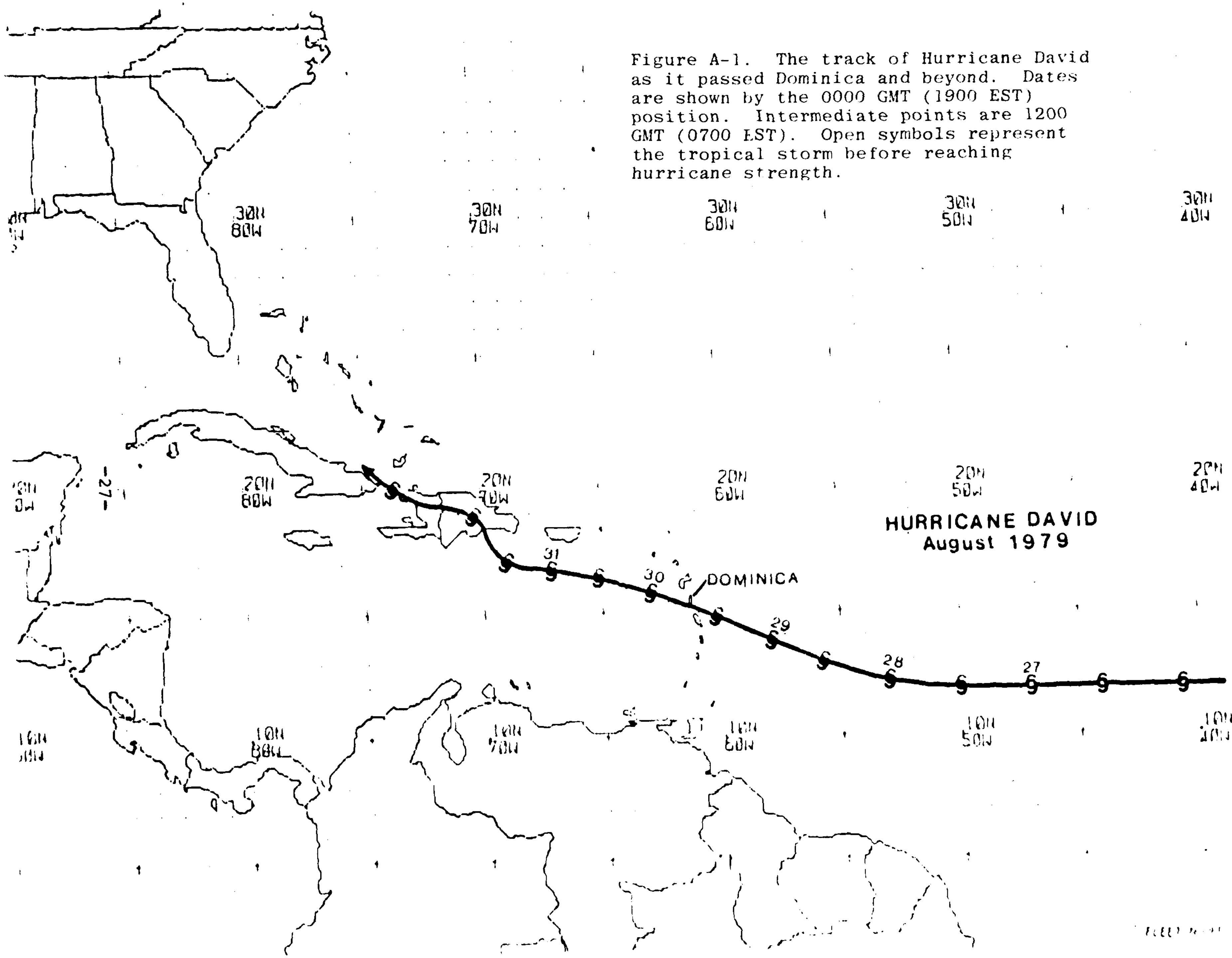


Figure A-1. The track of Hurricane David as it passed Dominica and beyond. Dates are shown by the 0000 GMT (1900 EST) position. Intermediate points are 1200 GMT (0700 EST). Open symbols represent the tropical storm before reaching hurricane strength.

Figure A-2. Depiction of the military forecasts for Hurricane David from 72hr prior to Dominica to 42hr prior to Dominica. Forecasts are given at 6hr intervals left to right, top to bottom. Dots represent the operational "nowcast" position, and the 12, 24, 48 and 72 hr forecast positions.

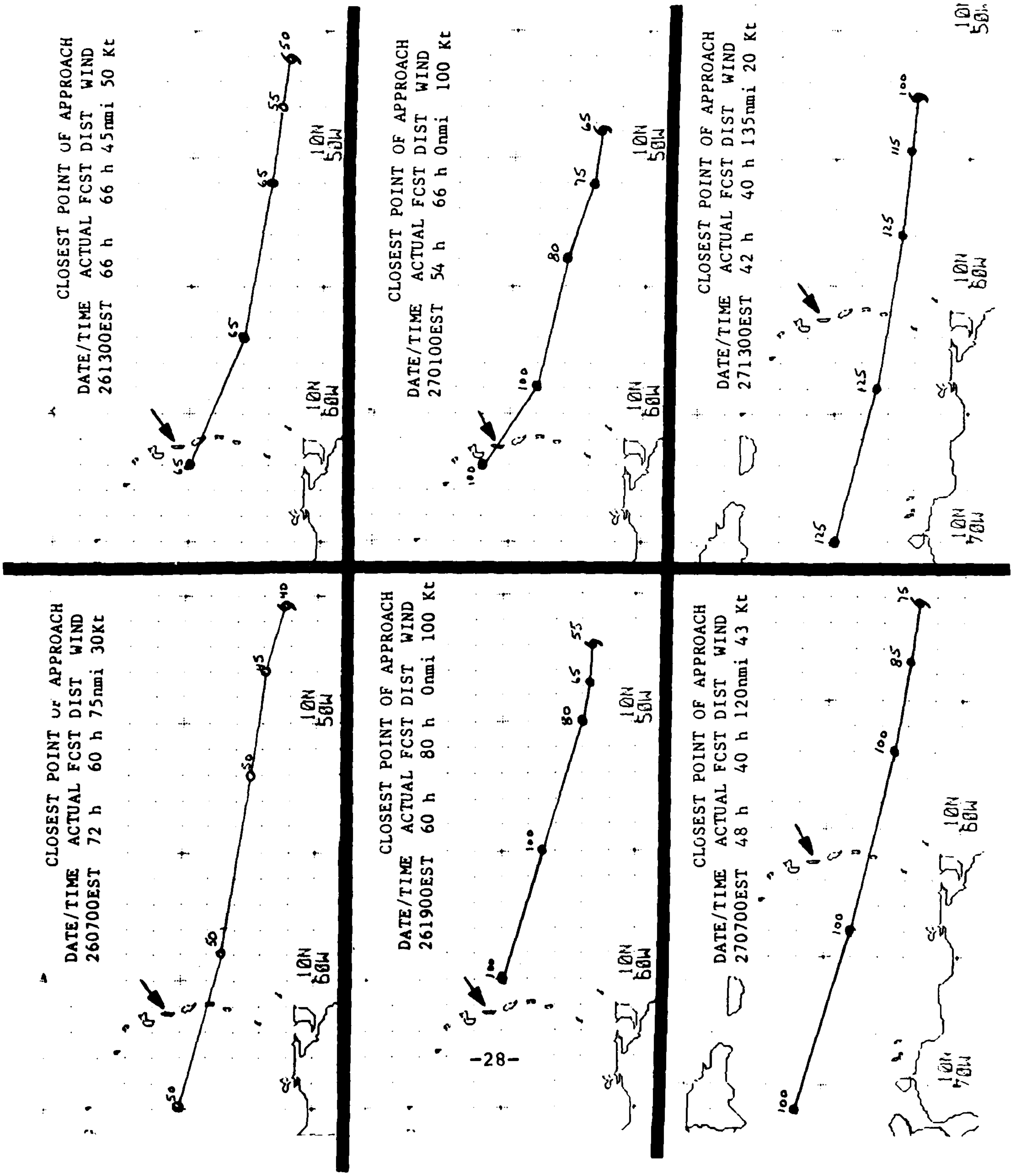


Figure A-3. Depiction of the military forecasts for Hurricane David from 36hr prior to Dominica until actual strike on Dominica. Forecasts are given at 6hr intervals left to right, top to bottom. Dots represent the operational "nowcast" position, and the 12, 24, 48 and 72 hr forecast positions.

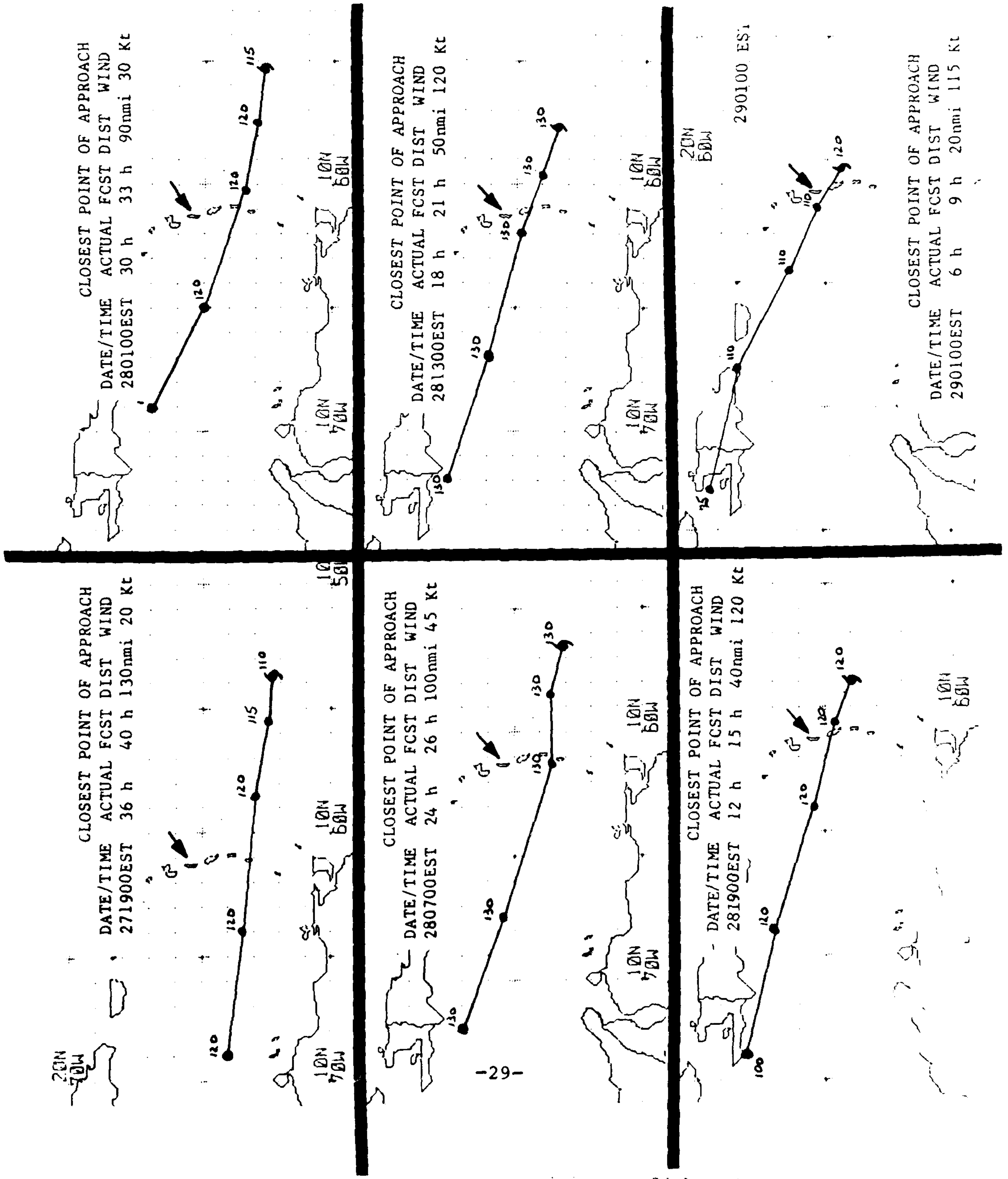


figure A-2 and the top of figure A-3. This trend remains rather constant until 18 hours lead time when the threat emphasis again shifts back to Dominica. Unfortunately this information would have reached Rosseau after nightfall when the ability to respond would have been severely limited. The actual warning arrived at daybreak along with the increasing winds as the event overtook the beginning of preparations with disasterous results.

As a demonstration of the utility of wind probabilities, the Navy wind probability model was run using the identical NHC military forecasts. Forecast probabilities of 50 kt and 30 kt winds were computed for Rosseau. These forecasts are given in Table A-1 along with the forecast maximum wind and the forecast passing distance at closest point of approach, both traditional indices of hurricane threat.

Notice that while the traditional indices follow an on-again, off-again wavering pattern fostering indecision, the probabilities derived from the same information show a solid pattern of steady progressive increase. As a threat index the probabilities properly allow for error and properly reveal a steady increase in the approaching danger.

Figure A-4 shows the joint probability plots of 50 kt and 30 kt winds for each forecast. The probabilities of 50 kt winds are on the vertical axis and the probability of 30 kt winds are on the horizontal axis. This display not only re-emphasizes the steadiness of the behavior of the probabilities over time, but also suggests that zones might be defined on this type display and identified with a hurricane watch (or warning) or with each of the military hurricane or typhoon readiness conditions.

Actual Time to Strike	Forecast Max Wind (kt)	Forecast CPA (nmi)	Forecast P50 %	Forecast P30 %
72hr	30	75	12	22
66hr	50	45	12	19
60hr	100	0	12	17
54hr	100	0	18	24
48hr	40	120	23	32
42hr	20	135	24	30
36hr	20	130	26	34
30hr	30	90	33	43
24hr	50	100	42	52
18hr	120	50	59	73
12hr	120	40	78	91
6hr	120	20	88	98

Table A-1

Comparison of traditional forecast indices of threat (maximum wind at Rosseau and closest point of approach (CPA)) to the probability of 50 and 30 kt winds.

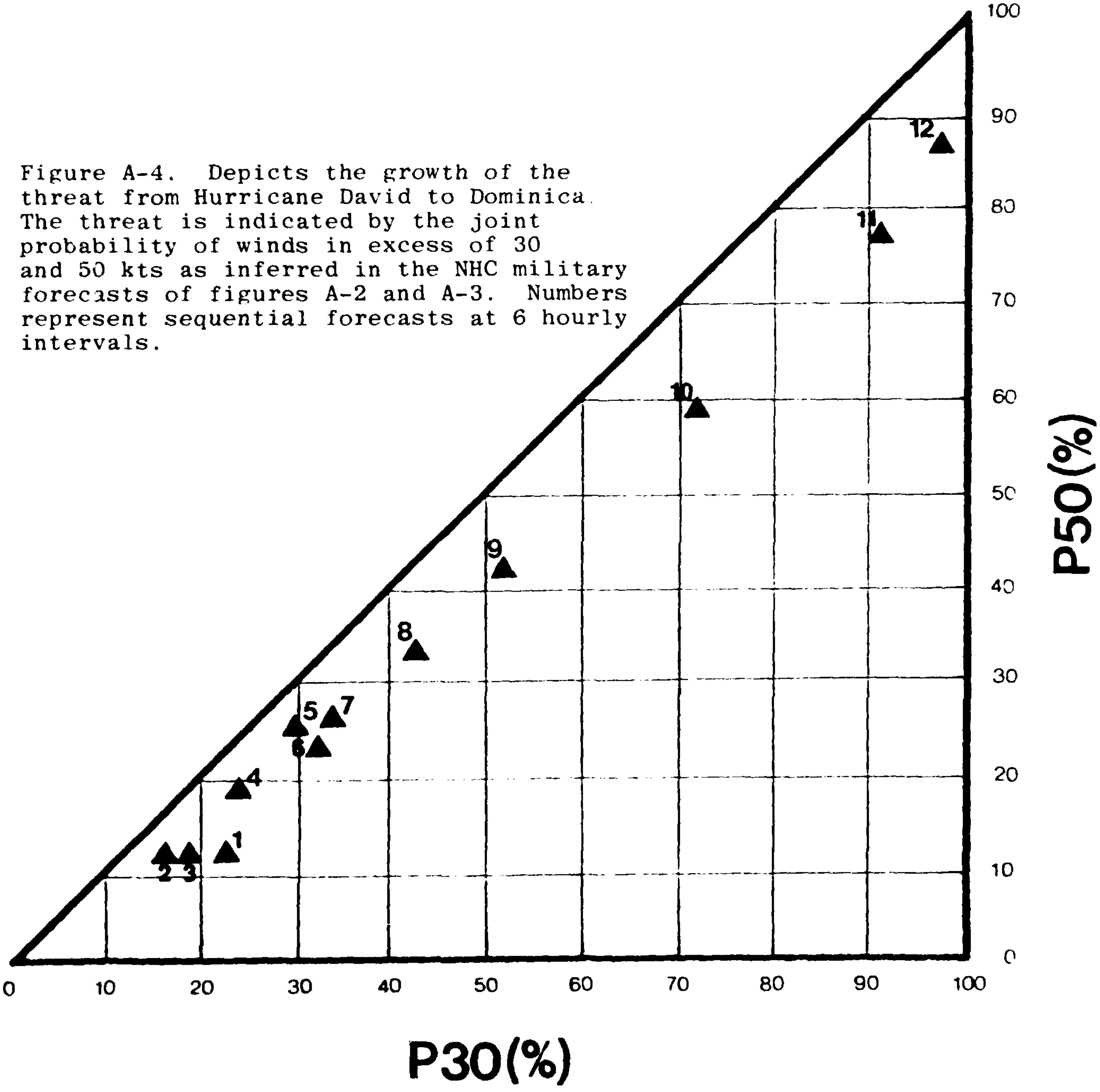


Figure A-4. Depicts the growth of the threat from Hurricane David to Dominica. The threat is indicated by the joint probability of winds in excess of 30 and 50 kts as inferred in the NHC military forecasts of figures A-2 and A-3. Numbers represent sequential forecasts at 6 hourly intervals.

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